COURSE DATA

Data Subject

Code	43306
Name	Nonlinear optics and lasers
Cycle	Master's degree
ECTS Credits	6.0
Academic year	2021 - 2022

Study (s)

Degree	Center	Acad. year	Period
2150 - Master's degree in Advanced Physics	Faculty of Physics	1	First term

Subject-matter

Degree	Subject-matter	Character
2150 - Master's degree in Advanced Physics	6 - Elements of advanced optics	Optional

Coordination

Name	Department
ROLDAN SERRANO, EUGENIO	280 - Optics and Optometry and Vision Sciences
VALCARCEL GONZALVO, GERMAN JOSE DE	280 - Optics and Optometry and Vision Sciences

SUMMARY

Under strong electromagnetic fields dielectric materials no more exhibit a linear response with respect to the electric field. In the optical domain this is what defines what is known as nonlinear optics, which is at the basis of modern photonics and quantum optics. The nonlinear response of the material media is the responsible for a number of phenomena, allowing for the generation of coherent radiation in spectral regions in which lasers are not effective, the non-invasive measurement of chemical substances, high-frequency modulation of optical radiation, or the generation of optical solitons, to cite a few. Commonly, nonlinear optical phenomena require large laser power, which is frequently obtained by using pulsed lasers. At the same time, the latter find many applications in material processing, in information transmission or in metrology, just to mention a few cases. The course pretends to provide an introduction to the physical basis of nonlinear optics and to some of its phenomena, as well as to laser physics.

PREVIOUS KNOWLEDGE

Relationship to other subjects of the same degree

There are no specified enrollment restrictions with other subjects of the curriculum.

Other requirements

COMPETENCES (RD 1393/2007) // LEARNING OUTCOMES (RD 822/2021)

2150 - Master's degree in Advanced Physics

- Students should demonstrate self-directed learning skills for continued academic growth.
- Students should possess and understand foundational knowledge that enables original thinking and research in the field.
- Ser capaz de gestionar información de distintas fuentes bibliográficas especializadas utilizando principalmente bases de datos y publicaciones internacionales en lengua inglesa.
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  ?
- Estar en disposición para seguir los estudios de doctorado y la realización de un proyecto de tesis doctoral.
  ?
  ?
- Comprender de una forma sistemática el campo de estudio de la Física y el dominio de las habilidades y métodos de investigación relacionados con dicho campo.
- Concebir, diseñar, poner en práctica y adoptar un proceso sustancial de investigación con seriedad académica.
- Realizar un análisis crítico, evaluación y síntesis de ideas nuevas y complejas en el área de la Física.
- Analizar una situación compleja extrayendo cuales son las cantidades físicas relevantes y ser capaz de reducirla a un modelo parametrizado.
- Evaluar la validez de un modelo o teoría propuesto por otros miembros de la comunidad científica.
- Saber modelizar matemáticamente los problemas físicos sencillos nuevos, conectados con problemas conocidos. Ser capaz de expresar en términos matemáticos nuevas ideas.
- Elaborar una memoria clara y concisa de los resultados de su trabajo y de las conclusiones obtenidas en el área de la Física.
- Exponer y defender públicamente el desarrollo, resultados y conclusiones de su trabajo en el área de la Física.
- Comprender los fundamentos físicos de la interacción de la luz con la materia.

- Asimilar las bases físicas de la emisión láser y las características fundamentales de los ?láseres de mayor interés para la fotónica.

LEARNING OUTCOMES (RD 1393/2007) // NO CONTENT (RD 822/2021)

At the end of the teaching-learning process the student will have learned:

1. Understanding and use of the optical properties of linear and nonlinear material resources to support the design and manufacture of photonic devices.
2. Understanding the physical basis of the interaction of light with matter, in particular the laser emission, and the study of the fundamental characteristics of lasers of interest for photonics.
3. Understanding the elements of the theories of the signal and the information underlying the design of photonic transmission, processing and storage.
4. Learning the modern techniques of optical instrumentation in both inspection systems as imaging devices.
5. Understanding recent developments in devices and emerging technologies relevant to optical instrumentation in different fields of science and technology.

DESCRIPTION OF CONTENTS

1. Introduction to nonlinear optics. The generalized Lorentz theory

What we mean by nonlinear optics. The linear Lorentz theory: solutions; application to the Faraday effect. Generalization of the theory. Influence of spatial symmetries on the type of nonlinearity. Quadratic nonlinearity: second harmonic generation, optical rectification, sum and difference frequency generation. Cubic nonlinearity: the Kerr effect and third harmonic generation.

2. The constitutive relation and nonlinear susceptibilities

The constitutive relation in media with temporal invariance. Nonlinear susceptibilities. Symmetries. Systematization of nonlinear polarization calculations.

3. Light propagation in nonlinear optical media

The time-independent nonlinear wave equation. The time-dependent nonlinear wave equation: group velocity and its dispersion.

4. Second-order nonlinear optics

Second harmonic generation. Sum- and difference-frequency generation. Phase matching. Optical parametric amplification and oscillation.

5. Third-order nonlinear optics

The Kerr effect. Self-phase modulation, cross-phase modulation and four-wave mixing. Nonlinear propagation of light pulses in fibers. Optical solitons. Nonlinear dispersion.

6. Interaction of light with two- and more level atoms

Einstein rate equations. The problem of population inversion. Pumping schemes in media of three- and four-level atoms. Examples of laser media.

7. Amplification and laser emission

Amplification of radiation in a medium with population inversion. Optical cavities. Laser emission: threshold. Relaxation oscillations. Types of lasers. Applications.

8. Pulsed lasers

Types of laser modulation: basic features of laser pulses. Applications. Q-switching. Active mode-locking: principles and modelling. Passive mode-locking.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	40,00	100
Other activities	4,00	100
Seminars	3,00	100
Development of group work	30,00	0
Study and independent work	58,00	0
Resolution of case studies	15,00	0
TOTAL	**150,00**	

TEACHING METHODOLOGY

MD1 - Standard theory lecture
MD3 - Problems solving
MD4 - Problems
MD5 - Seminars

EVALUATION

In the evaluation of the course "Nonlinear Optics and Lasers" the following aspects will be considered:
- Attendance: regular attendance and active participation in the classroom. (25%)
- Exercises: solving a series of exercises (about five) proposed along the course. (35%)
- Preparation and submission of a report that will cover aspects and topics not developed during the course. This will be made in couples. (40%)
- Examination: for students who wish to improve the qualification obtained with the above criteria. In this case the exam will be the mark of the subject.

REFERENCES

Basic

- P.N. Butcher and D. Cotter, The Elements of Nonlinear Optics (Cambridge University Press, 1990)
- R.W. Boyd, Nonlinear Optics (Academic Press, 1992)
- G.P. Agrawal, Nonlinear Fiber Optics (Academic Press, 1995)
- A. Siegman, Lasers (University Science Dooks, 1986)
- O. Svelto, Principles of Lasers (Plenum Press, 1989)

ADDENDUM COVID-19

This addendum will only be activated if the health situation requires so and with the prior agreement of the Governing Council

English version is not available